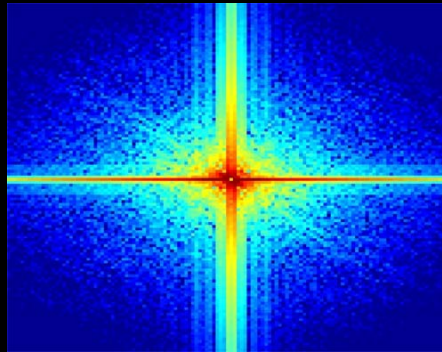


# Spectral Processing of Point-sampled Geometry

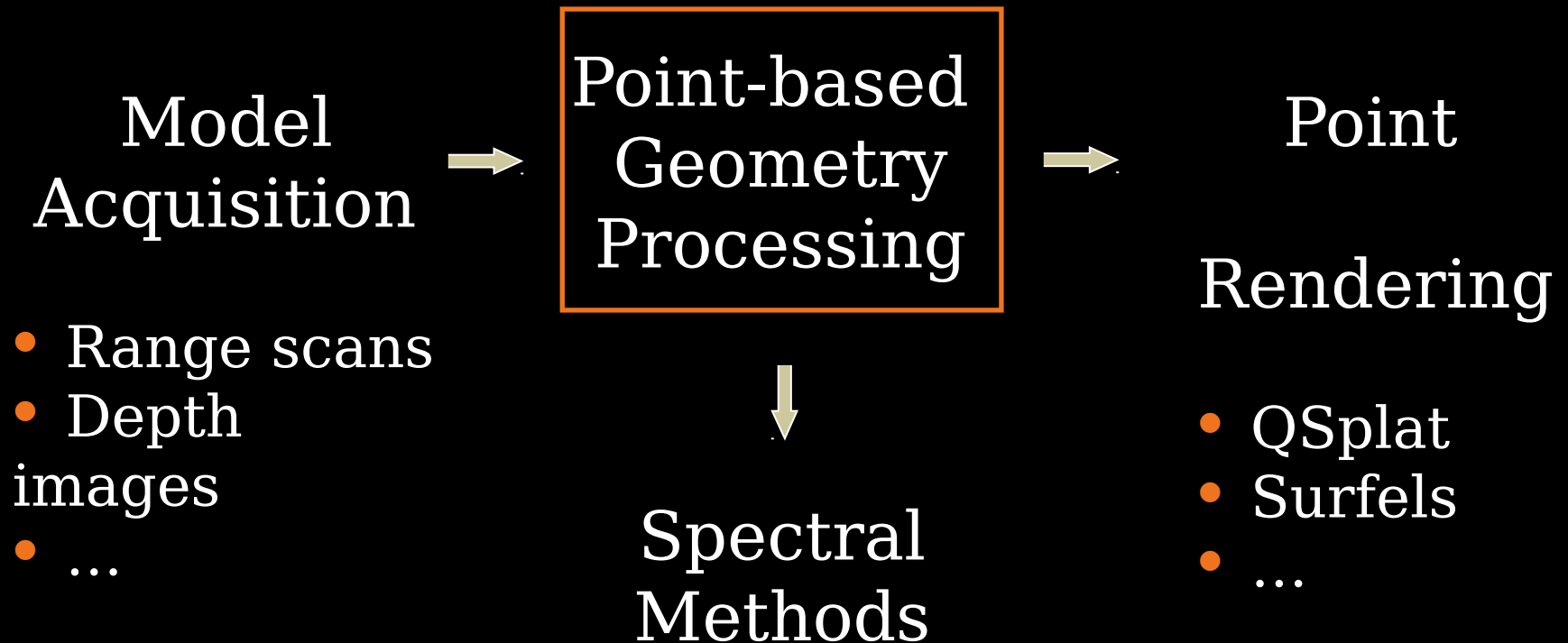


**Mark Pauly      Markus Gross**  
**ETH Zürich**

# Outline

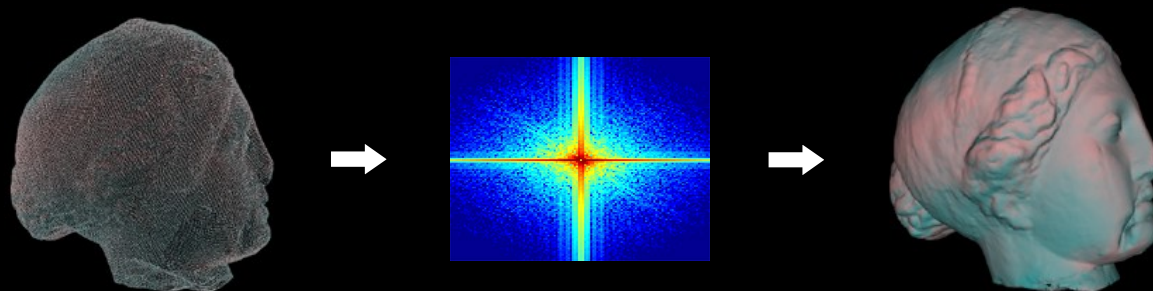
- Introduction
- Spectral processing pipeline
- Results
- Conclusions

# Introduction



# Spectral Transform

- Extend Fourier transform to 2-manifold surfaces



- ⇒ Spectral representation of point-based objects
- ⇒ Powerful methods for digital geometry processing

# Applications

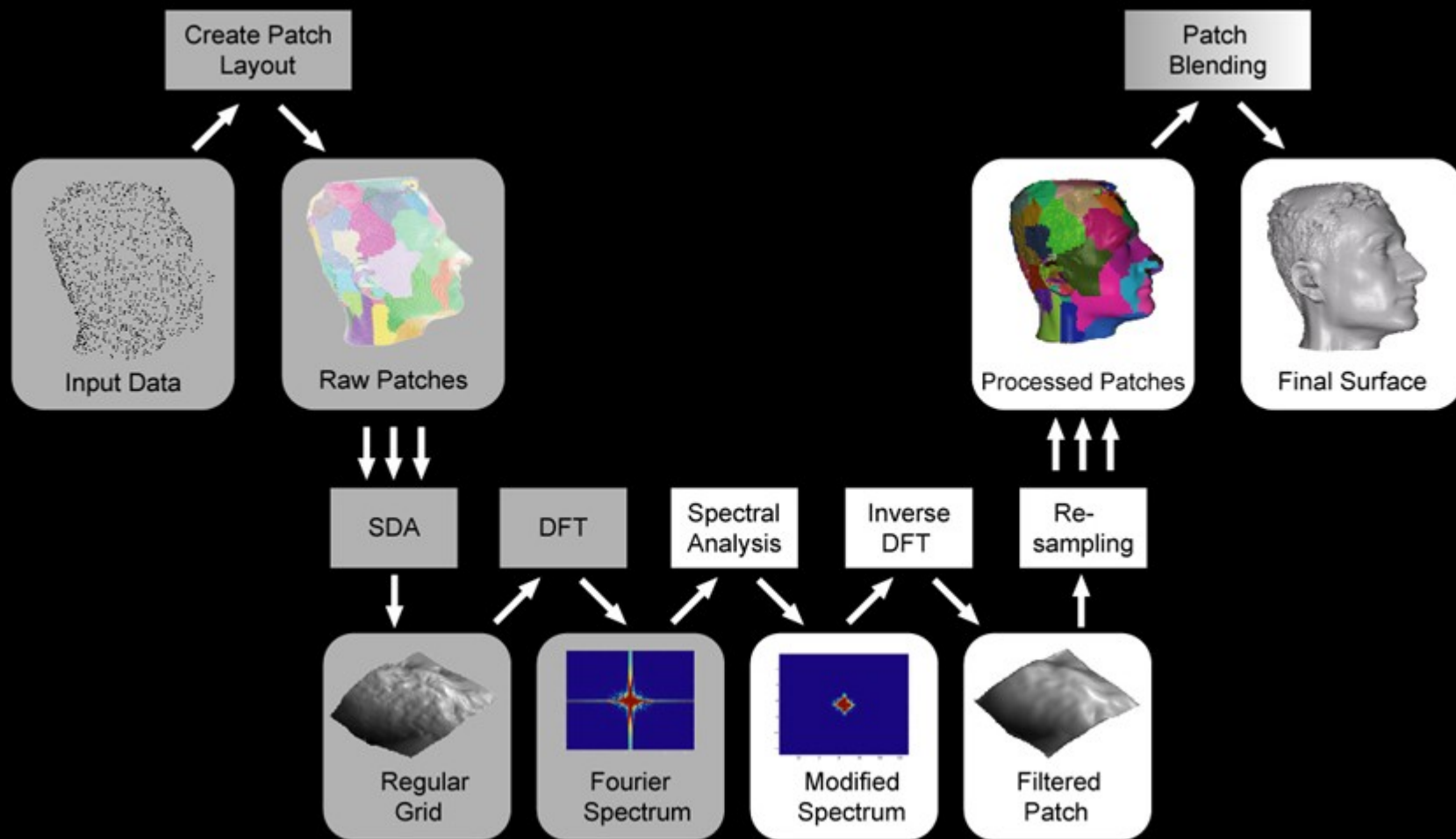
- Spectral filtering:
  - Noise removal
  - Microstructure analysis
  - Enhancement
- Adaptive resampling:
  - Complexity reduction
  - Continuous LOD

# Fourier Transform

$$X_n = \sum_{k=1}^N x_k e^{-j2\pi \frac{nk}{N}}$$

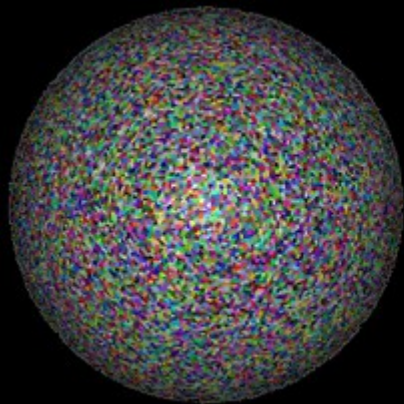
- Benefits:
  - Sound concept of frequency
  - Extensive theory
  - Fast algorithms
- Limitations:
  - Euclidean domain, global parameterization
  - Regular sampling
  - Lack of local control

## Overview

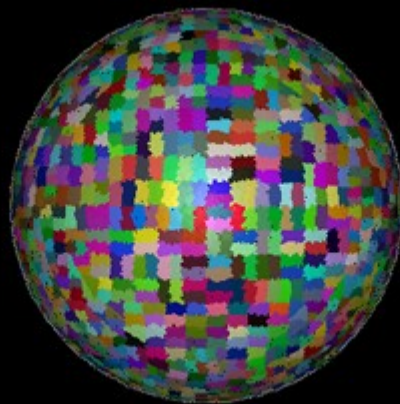


# Patch Layout Generation

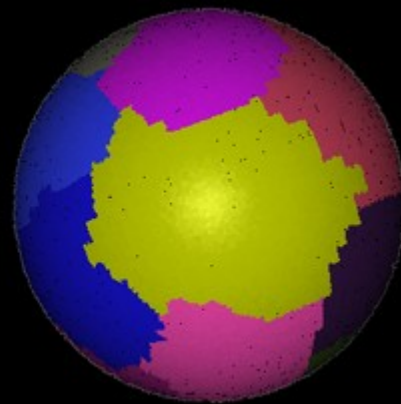
Clustering  $\Rightarrow$  Optimization



Samples



Clusters



Patches

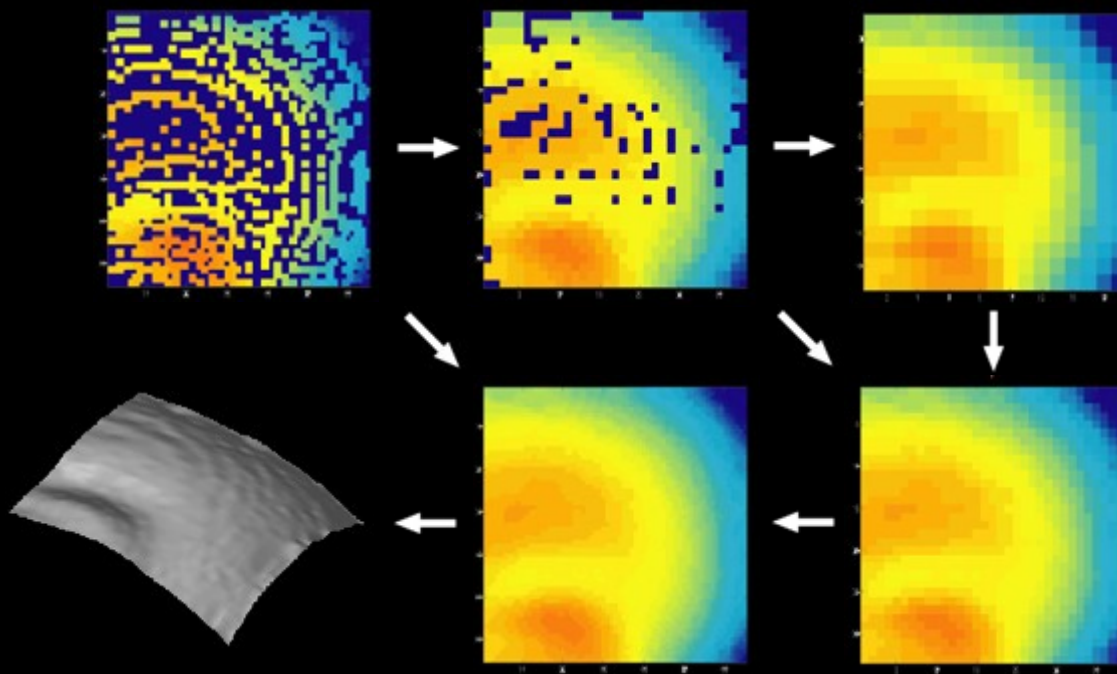
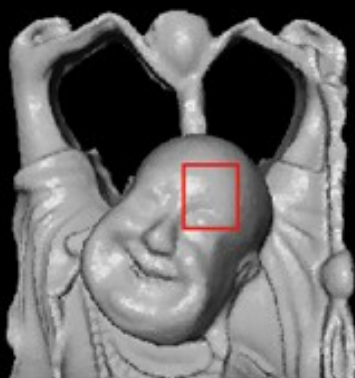


# Patch Merging Optimization

- Iterative, local optimization method
- Quality metric:
  - ⇒ patch Size
  - ⇒ curvature
  - ⇒ patch boundary
  - ⇒ spring energy regularization

# Scattered Data Approximation

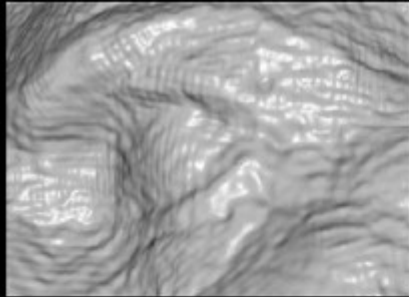
Hierarchical Push-Pull Filter:



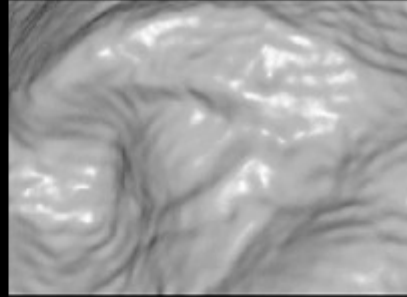
# Spectral Analysis

- 2D Discrete Fourier Transform (DFT)
  - ⇒ Direct manipulation of spectral coefficients
- Filtering as convolution:
  - ⇒ Convolution:  $O(N^2)$  ⇒ Multiplication:  $O(N)$
- Inverse Fourier Transform
  - ⇒ Filtered patch surface

# Spectral Analysis



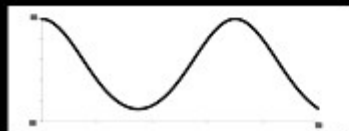
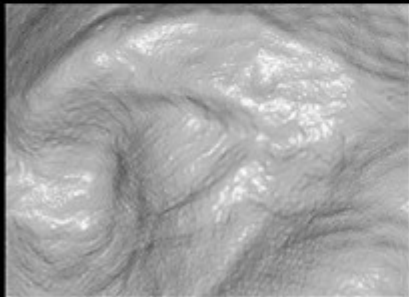
Ideal low-pass



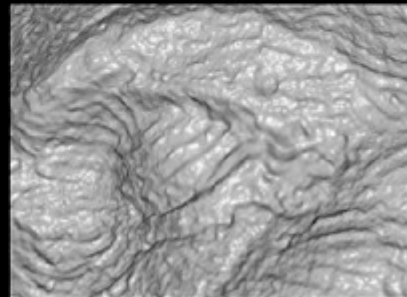
Gaussian low-pass



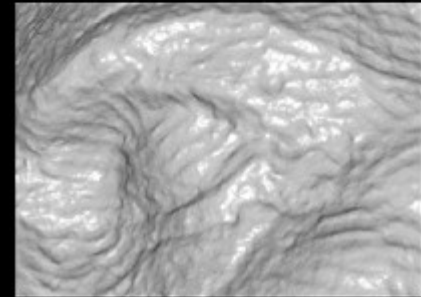
Original



Band-stop

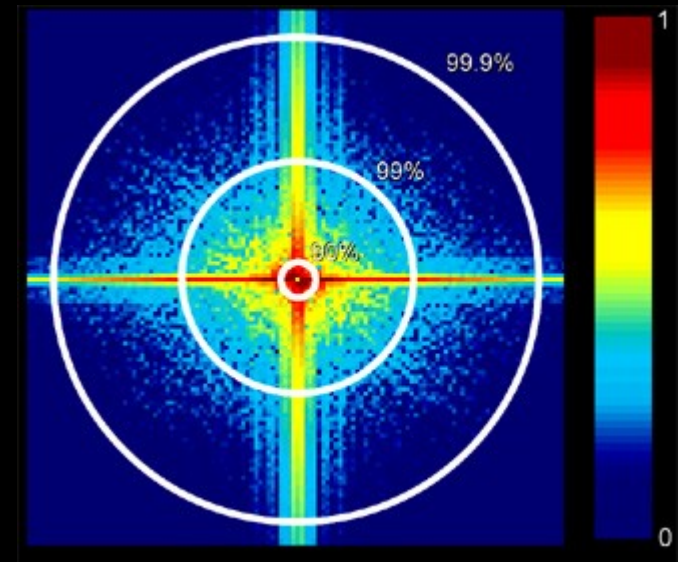


Enhancement



# Resampling

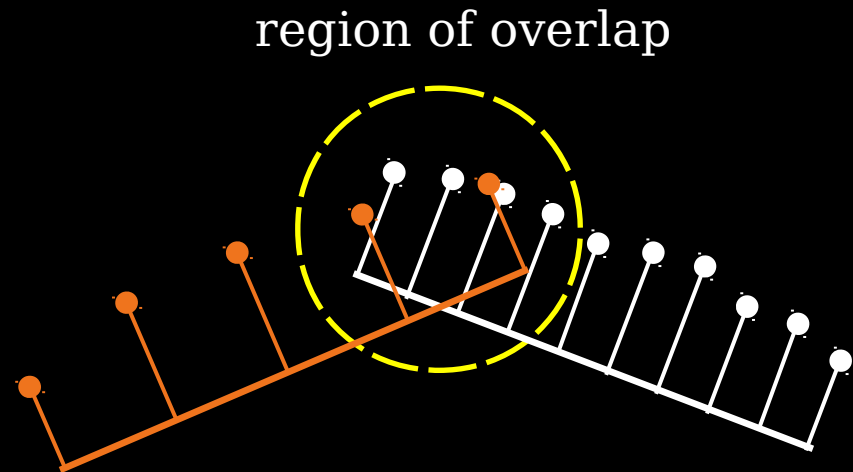
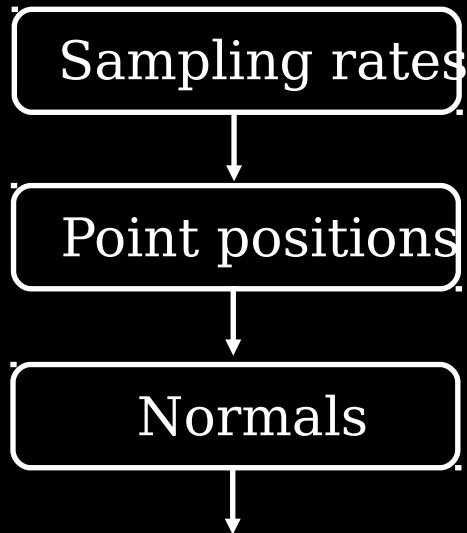
- Low-pass filtering
  - ⇒ Band-limitation
- Regular Resampling
  - ⇒ Optimal sampling rate (Sampling Theorem)
  - ⇒ Error control (Parseval's Theorem)



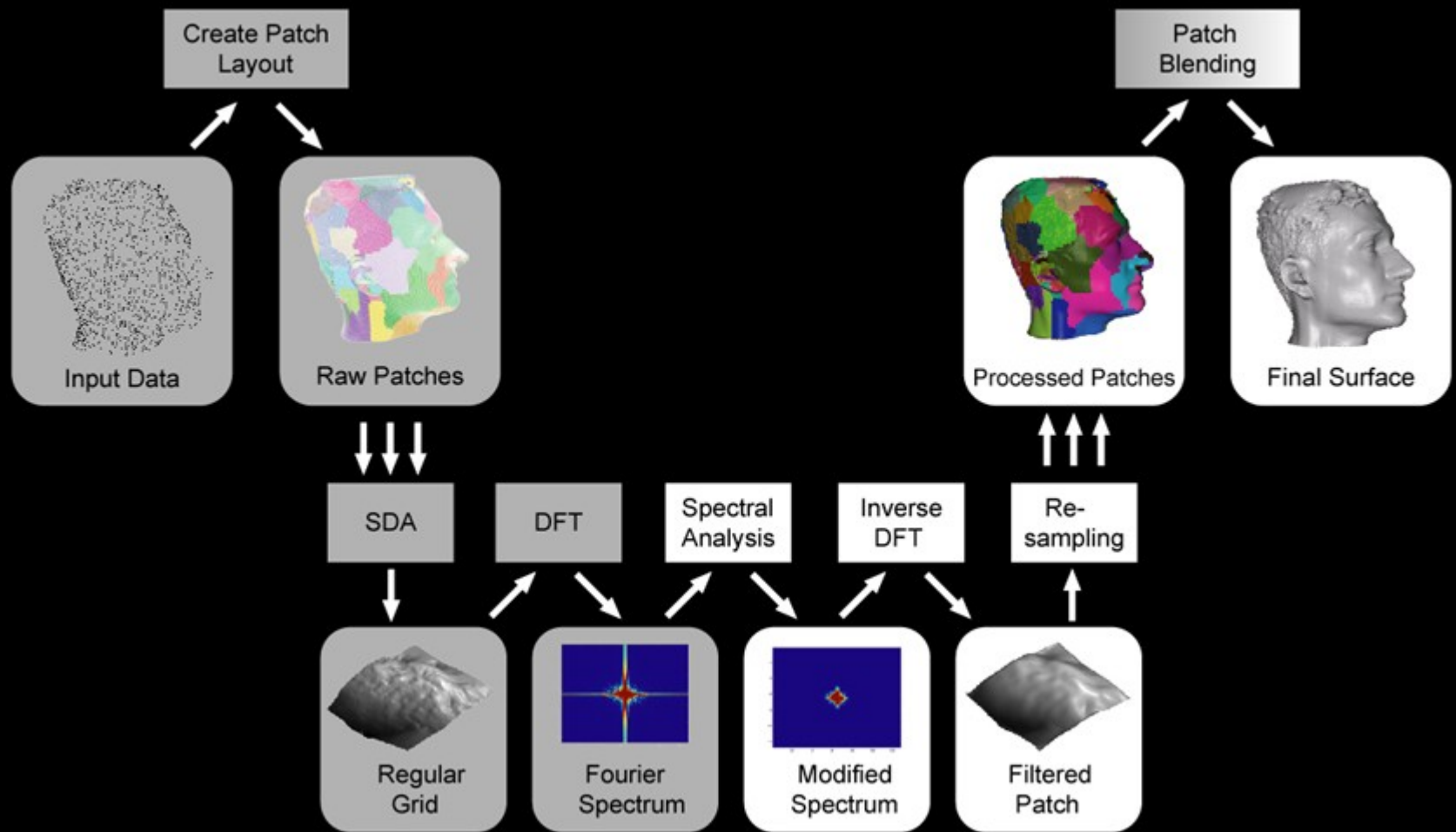
Power Spectrum

# Reconstruction

- Filtering can lead to discontinuities at patch boundaries
  - ⇒ Create patch overlap, blend adjacent patches



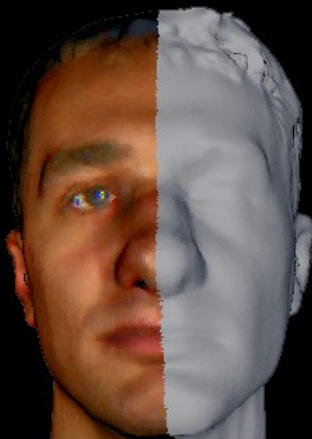
# Spectral Processing Pipeline



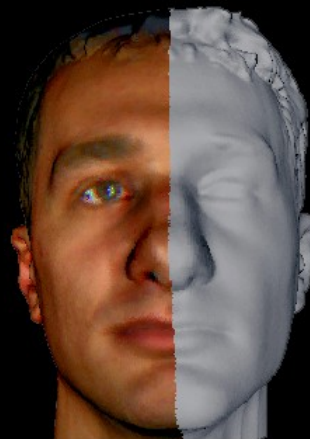
# Surface Restoration



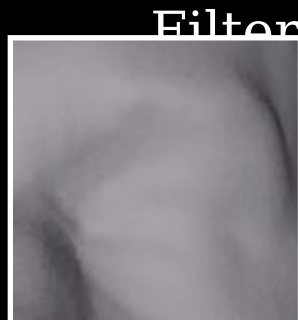
Original  
Patch



Gaussian

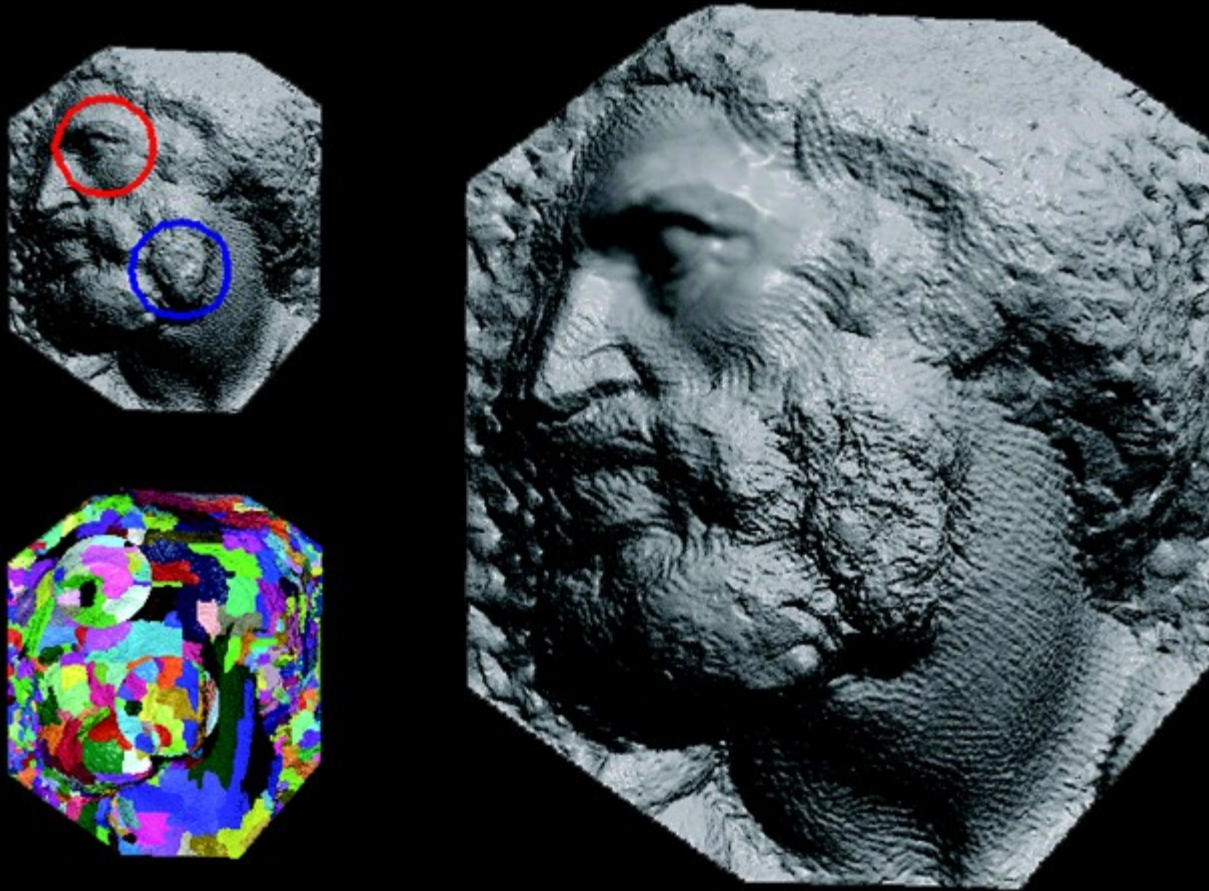


Wiener





# Interactive Filtering



# Adaptive Subsampling



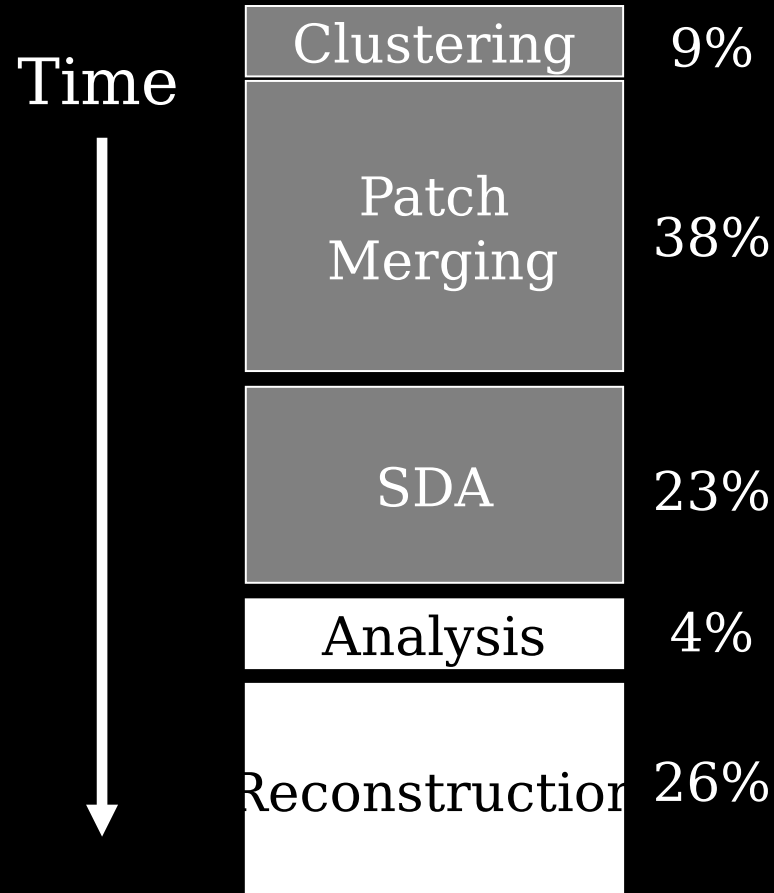
4,128,614 pts.  
= 100%






287,163 pts.  
= 6.9%



# Timings



# Timings

			
		M. w	d
#points	460,800	3,382,866	4,614
#patches	256	595	2,966
Preprocess	10.9	117.2	128.3
Total	15.8	153.0	189.6

# Summary

- Versatile spectral decomposition of point-based models
- Effective filtering
- Adaptive resampling
- Efficient processing of large point-sampled models

# Future Work

- Compression
  - ⇒ Scalar Representation + Spectral Compression
- Hierarchical Representation
  - ⇒ Modeling and Animation
- Feature Detection & Extraction
  - ⇒ Robust Computation of Laplacian

# Acknowledgements

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